MOTOROLA
Semiconductor Products Inc.

AN-780
Application Note

APPLICATIONS OF THE MOC3011 TRIAC DRIVER

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This note describes methods of applying the MOC3011 optically coupled triac driver to provide simple and effective interfaces from logic or microprocessor systems to AC power systems.

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DESCRIPTIONS OF THE MOC3011

Construction

The MOC3011 consists of a gallium arsenide infrared LED optically exciting a silicon detector chip, which is especially designed to drive triacs controlling loads on the 115 Vac power line. The detector chip is a complex device which functions in much the same manner as a small triac, generating the signals necessary to drive the gate of a larger triac. The MOC3011 allows a low power exciting signal to drive a high power load with a very small number of components, and at the same time provides practically complete isolation of the driving circuitry from the power line.

The construction of the MOC3011 follows the same highly successful coupler technology used in Motorola's broad line of plastic couplers (Figure 1). The dual lead frame with a clear epoxy undermold provides a stable dielectric capable of sustaining 7.5 kV between the input and output sides of the device. The detector chip is passivated with silicon nitride and uses Motorola's annular ring to maintain stable breakdown parameters.

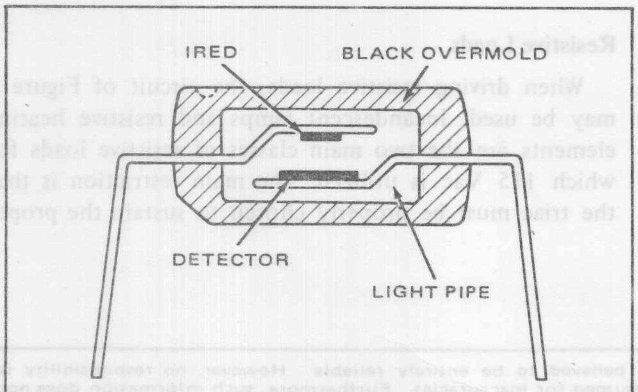


FIGURE 1 – Motorola Double-Molded Coupler Package

Basic Electrical Description

The GaAs LED has nominal 1.3 V forward drop at 10 mA and a reverse breakdown voltage greater than 3 V. The maximum current to be passed through the LED is 50 mA.

The detector has a minimum blocking voltage of 250 Vdc in either direction in the off state. In the on state, the detector will pass 100 mA in either direction with less than 3 V drop across the device. Once triggered into the on (conducting) state, the detector will remain there until the current drops below the holding current (typically 100 μA) at which time the detector reverts to the off (non-conducting) state. The detector may be triggered into the on state by exceeding the forward blocking voltage, by voltage ramps across the detector at rates exceeding the static dv/dt rating, or by photons from the LED. The LED is guaranteed by the specifications to trigger the detector into the on state when 10 mA or more is passed through the LED.

USING THE MOC3011 ALONE

In some applications, the MOC3011 may be used by itself, driving the load directly. The MOC3011 alone can, for example, switch a 7-1/2 watt 115 Vac light bulb. This lamp is sufficiently bright to be a useful warning light to attract attention to a serious malfunction in a micro-

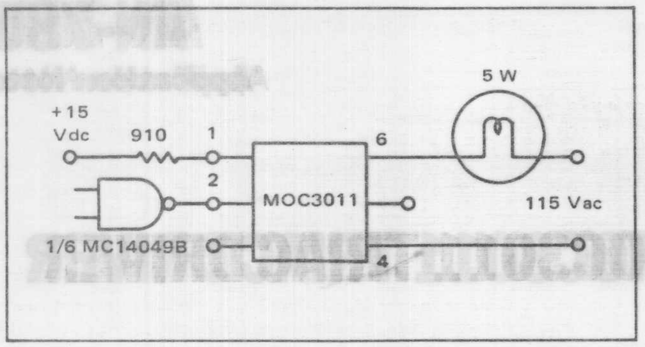


FIGURE 2 — MOC3011 Interfacing Between McMOS and a 115 Vac Alarm Lamp

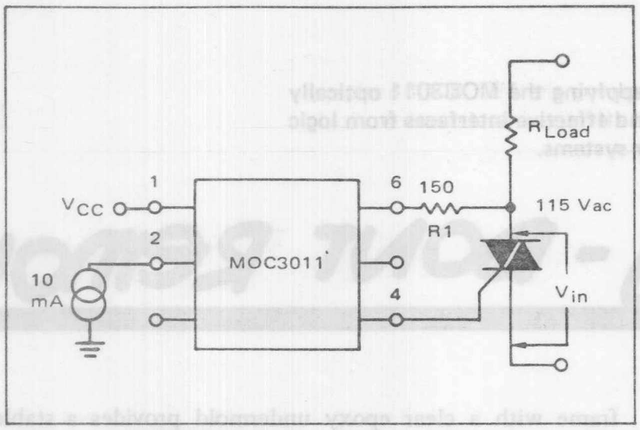
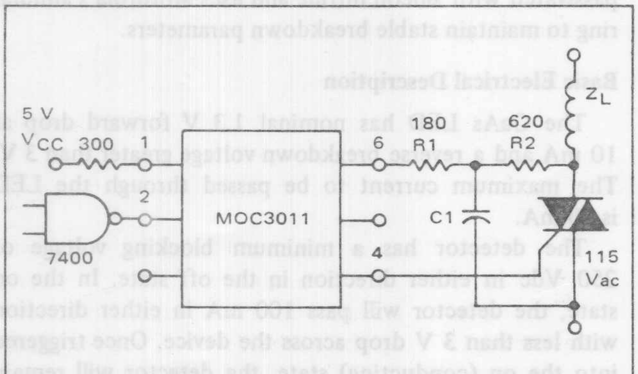


FIGURE 3 — Simple Triac Gating Circuit



NOTE: Circuit supplies 25 mA drive to gate of triac at V_{in} = 25 V and $T_A \leqslant 70^{\circ}C$.

LOAD POWER FACTOR	C
1.0	0
0.75	0.22 μF
0.5	0.33 μF

FIGURE 4 — Logic to Inductive Load Interface

computer or other logic assembly. Figure 2 shows how to interface between McMOS and a 7-1/2 watt light bulb. The MOC3011, a resistor, and the light bulb are the only components used, and there is practically complete isolation between the ac line and the delicate logic array.

Power Dissipation

The load that the MOC3011 can drive by itself is limited by the maximum allowable internal power dissipation. The device is specified to be able to handle 50 mA RMS current at 70°C. Since the 5 Watt bulb shown in Figure 2 will only draw 40 mA RMS continuous, this condition is satisfied over the 0-70°C operating range of the MOC3011.

Inrush Current

When driving an incandescent light bulb, the turn-on current can be about ten times the normal steady-state current, because the resistance of a cold filament is much less than the resistance of a hot filament. The MOC3011's maximum rated surge current, is 1.2 A, which is sufficient to prevent trouble when driving small loads directly.

USING THE MOC3011 AS A TRIAC DRIVER

Triac Driving Requirements

Figure 3 shows a simple triac driving circuit using the MOC3011. The maximum surge current rating of the MOC3011 sets the minimum value of R1 through the equation:

$$R1(min) = V_{in}(pk)/1.2\ A$$

If we are operating on the 115 Vac line voltage, $V_{in}(pk)$ = 162 V, then

$$R1(min) = V_{in}(pk)/1.2\ A = 136\ ohms.$$

In practice, this would be a 150 or 180 ohm resistor. If the triac has I_{GT} = 100 mA and V_{GT} = 2 V, then the voltage V_{in} necessary to trigger the triac will be given by $V_{inT} = R1 \cdot I_{GT} + V_{GT} + V_{TM} = 20$ V.

Resistive Loads

When driving resistive loads, the circuit of Figure 3 may be used. Incandescent lamps and resistive heating elements are the two main classes of resistive loads for which 115 Vac is utilized. The main restriction is that the triac must be properly chosen to sustain the proper

inrush loads. Incandescent lamps can sometimes draw a peak current known as "flashover" which can be extremely high, and the triac should be protected by a fuse or rated high enough to sustain this current.

Line Transients–Static dv/dt

Occasionally transient voltage disturbance on the ac line will exceed the static dv/dt rating of the MOC3011. In this case, it is possible that the MOC3011 and the associated triac will be triggered on. This is usually not a problem, except in unusually noisy environments, because the MOC3011 and its triac will commute off at the next zero crossing of the line voltage, and most loads are not noticeably affected by an occasional single half-cycle of applied power. See Figure 5 for typical dv/dt versus temperature curves.

Inductive Loads–Commutating dv/dt

Inductive loads (motors, solenoids, magnets, etc.) present a problem both for triacs and for the MOC3011 because the voltage and current are not in phase with each other. Since the triac turns off at zero current, it may be trying to turn off when the applied current is zero but the applied voltage is high. This appears to the triac like a sudden rise in applied voltage, which turns on the triac if the rate of rise exceeds the commutating dv/dt of the triac or the static dv/dt of the MOC3011.

Snubber Networks

The solution to this problem is provided by the use of "snubber" networks to reduce the rate of voltage rise seen by the device. In some cases, this may require two snubbers–one for the triac and one for the MOC3011. The triac snubber is dependent upon the triac and load used and will not be discussed here. In many applications the snubber used for the MOC3011 will also adequately protect the triac.

In order to design a snubber properly, one should really know the power factor of the reactive load, which is defined as the cosine of the phase shift caused by the load. Unfortunately, this is not always known, and this makes snubbing network design somewhat empirical. However a method of designing a snubber network may be defined, based upon a typical power factor. This can be used as a "first cut" and later modified based upon experiment.

Assuming an inductive load with a power factor of PF = 0.5 is to be driven. The triac might be trying to turn off when the applied voltage is given by

$$V_{to} = V_{pk} \sin \phi = 115 \sqrt{2}\, 0.87 = 142\ \text{V}$$

First, one must choose R1 (Figure 4) to limit the peak capacitor discharge current through the MOC 3011. This resistor is given by

$$R1 = V_{pk}/I_{max} = 115 \sqrt{2}/1.2\ \text{A} = 136\ \Omega$$

A standard value, 180 ohm resistor would be used in practice for R1.

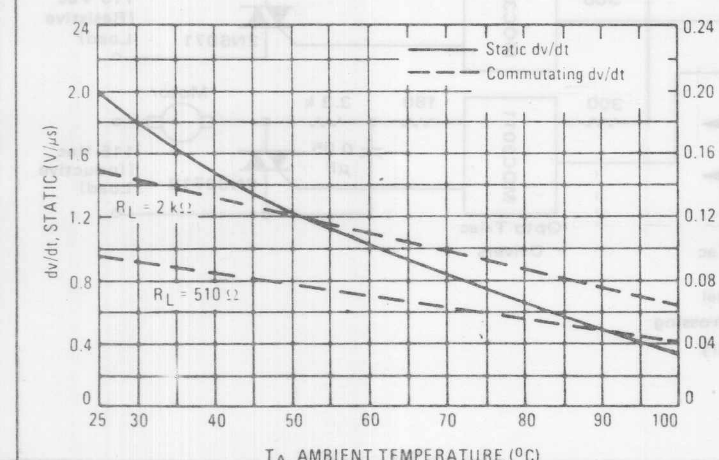
It is necessary to set the time constant for $\tau = R_2C$. Assuming that the triac turns off very quickly, we have a peak rate of rise at the MOC3011 given by

$$dv/dt = V_{to}/\tau = V_{to}/R_2C$$

Setting this equal to the worst case dv/dt (static) for the MOC3011 which we can obtain from Figure 5 and solving for R_2C:

$$dv/dt(T_J = 100^oC) = 0.4\ \text{V}/\mu s = 4 \times 10^5$$

$$R_2C = V_{to}/(dv/dt) = 142/(4 \times 10^5) = 353 \times 10^{-6}$$



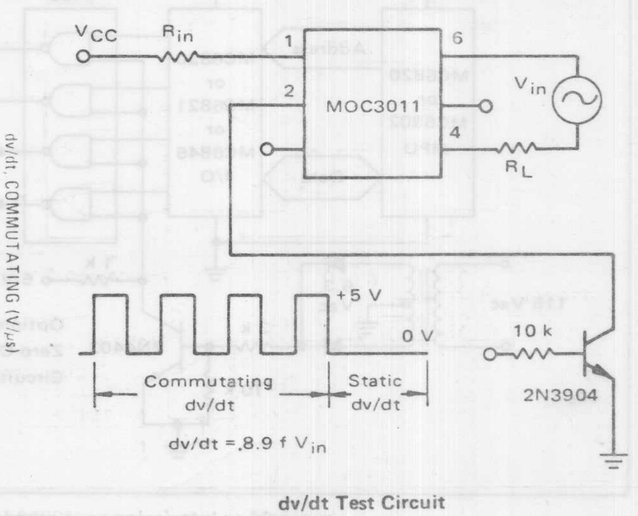


FIGURE 5 – dv/dt versus Temperature

The largest value of R2 available is found, taking into consideration the triac gate requirements. If a sensitive gate triac is used, such as a 2N6071B, I_{GT} = 15 mA @ −40°C. If the triac is to be triggered when V_{in} = 25 V,

$$(R1 + R2) = (25 - V_{TM}(25\ mA) - V_{GT}/0.015\ mA = 1200\ \Omega$$

If R2 = 1200 ohms and C = 0.3 μF, the conditions for snubbing the MOC3011 are satisfied. Actually, this is an example of "worst case" design, so that normal snubber capacitors will not be so large. Practical capacitor values can usually be lower because most equipment does not have to designed for operation at −40°C or +100°C. Designing for a more limited temperature range, 0° to 70°C, allows the capacitor to be smaller, 0.02 to 0.1 μF. The capacitor introduces some leakage around the triac, and this value should be calculated. In the case of a 0.3 μF capacitor and R2 = 1200 ohms, this leakage current will be about 12 mA. A typical snubber network is shown in Figure 4.

INPUT CIRCUITRY

Resistor Input

When the input conditions are well controlled, as for example when driving the MOC3011 from a TTL, DTL, or HTL gate, only a single resistor is necessary to interface the gate to the input LED of the MOC3011. This resistor should be chosen to set the current into the LED to be a minimum of 10 mA but no more than 50 mA. 15 mA is a suitable value, which allows for considerable degradation of the LED over time, and assures a long operating life for the coupler. Currents higher than 15 mA do not improve performance and may hasten the aging process inherent in LED's. Assuming the forward drop to be 1.5 V at 15 mA allows a simple formula to calculate the input resistor.

$$R_i = (V_{CC} - 1.5)/0.015$$

Examples of resistive input circuits are seen in Figures 2 and 6.

Increasing Input Sensitivity

In some cases, the logic gate may not be able to source or sink 15 mA directly. CMOS, for example, is specified to have only 0.5 mA output, which must then be increased to drive the MOC3011. There are numerous ways to increase this current to a level compatible with the MOC3011 input requirements; an efficient way is to use the MC14049B shown in Figure 6. Since there are six such buffers in a single package, the user can have a small package count when using several MOC3011's in one system.

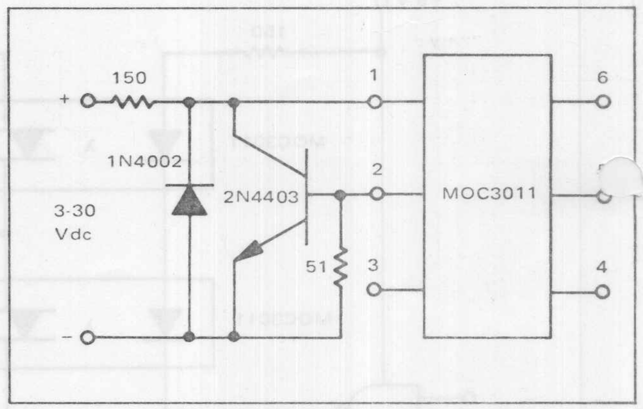
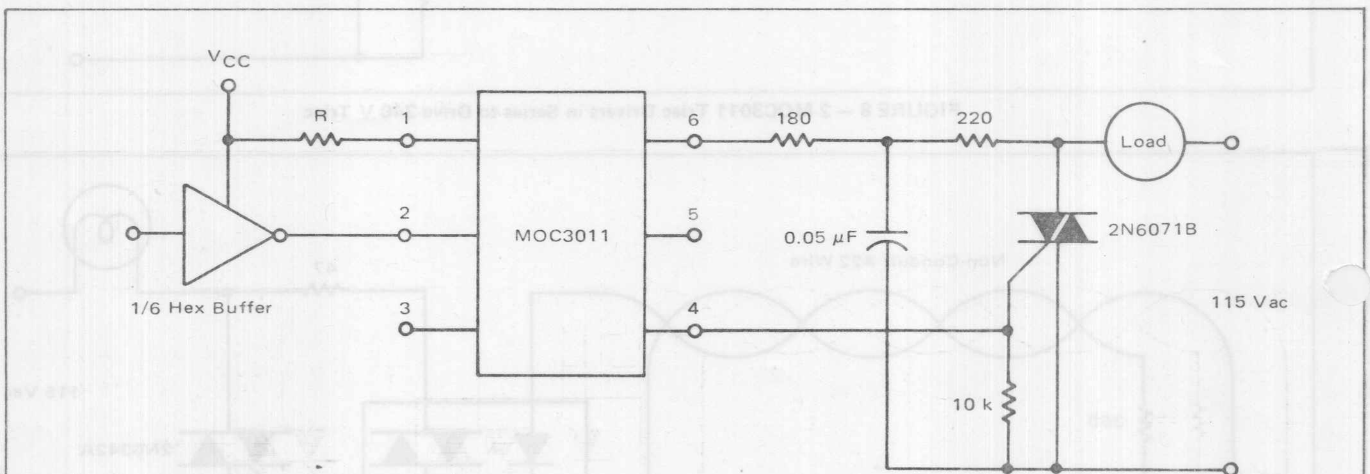


FIGURE 7 – MOC3011 Input Protection Circuit



V_{CC}	R	HEX BUFFER
5.0 V	220 Ω	MC75492
10 V	600 Ω	MC75492
15 V	910 Ω	MC14049B

FIGURE 6 – MOS to ac Load Interface

Input Protection Circuits

In some applications, such as solid state relays, in which the input voltage varies widely the designer may want to limit the current applied to the LED of the MOC3011. The circuit shown in Figure 7 allows a non-critical range of input voltages to properly drive the MOC3011 and at the same time protects the input LED from inadvertent application of reverse polarity.

LED Lifetime

All light emitting diodes slowly decrease in brightness during their useful life, an effect accelerated by high temperatures and high LED currents. To allow a safety margin and insure long service life, the MOC3011 is actually tested to trigger at a value lower than the specified 10 mA input threshold current. The designer can therefore design the input circuitry to supply 10 mA to the LED and still be sure of satisfactory operation over a long operating lifetime. On the other hand, care should be taken to insure that the maximum LED input current (50 mA) is not exceeded or the lifetime of the MOC3011 may be shortened.

APPLICATIONS EXAMPLES

Using the MOC3011 on 240 Vac Lines

The rated voltage of a MOC3011 is not sufficiently high for it to be used directly on 240 Vac line; however, the designer may stack two of them in series. When used this way, two resistors are required to equalize the voltage dropped across them as shown in Figure 8.

Remote Control of ac Voltage

Local building codes frequently require all 115 Vac light switch wiring to be enclosed in conduit. By using a MOC3011, a triac, and a low voltage source, it is

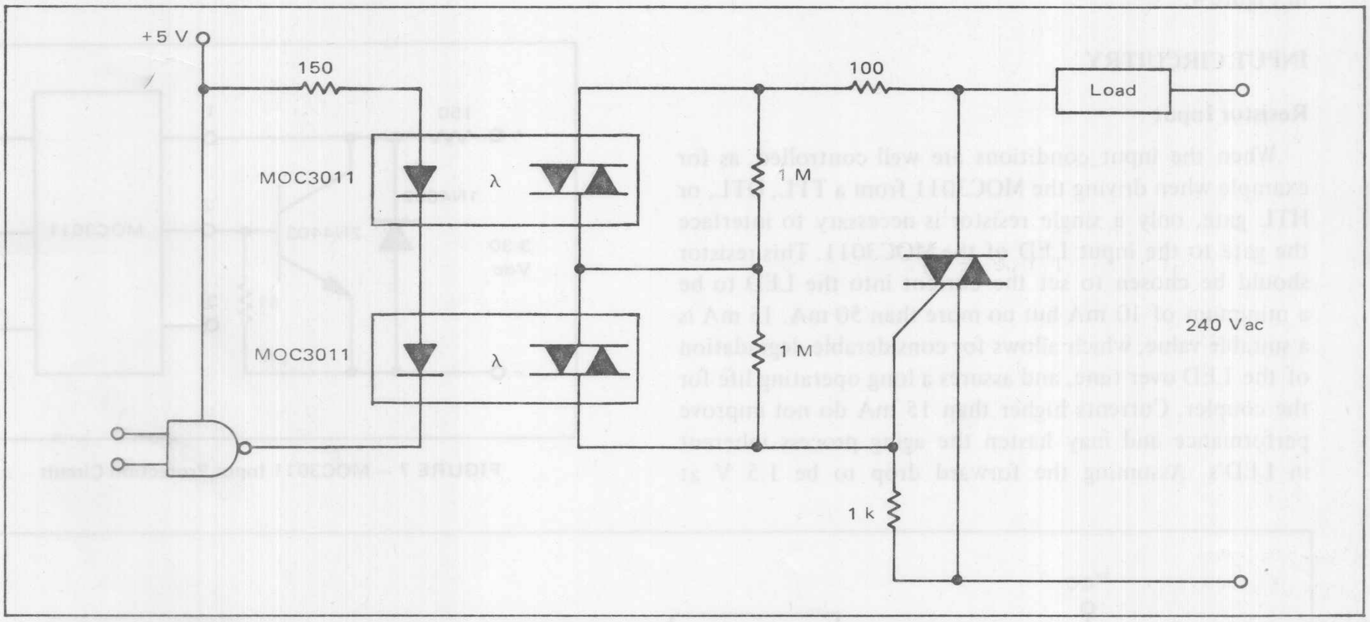


FIGURE 8 – 2 MOC3011 Triac Drivers in Series to Drive 240 V Triac

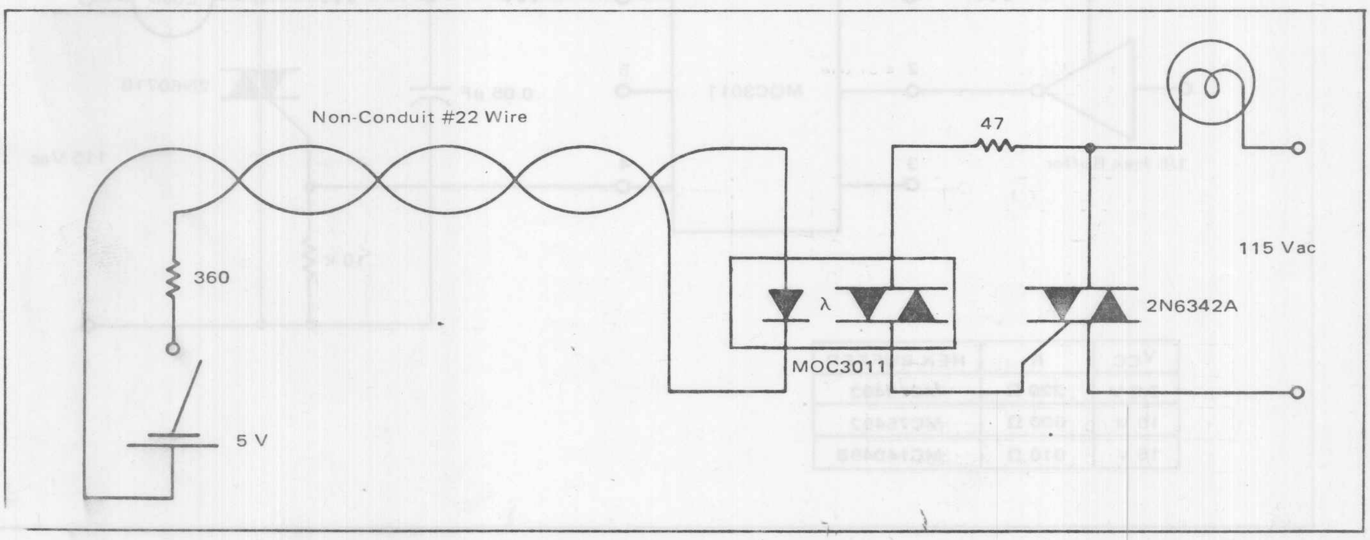


FIGURE 9 – Remote Control of ac Loads Through Low Voltage Non-Conduit Cable

possible to control a large lighting load from a long distance through low voltage signal wiring which is completely isolated from the ac line. Such wiring usually is not required to be put in conduit, so the cost savings in installing a lighting system in commercial or residential buildings can be considerable. An example is shown in Figure 9. Naturally, the load could also be a motor, fan, pool pump, etc.

Solid State Relay

Figure 10 shows a complete general purpose, solid state relay snubbed for inductive loads with input protection. When the designer has more control of the input and output conditions, he can eliminate those components which are not needed for his particular application to make the circuit more cost effective.

Interfacing Microprocessors to 115 Vac Peripherals

The output of a typical microcomputer input-output (I/O) port is a TTL-compatible terminal capable of driving one or two TTL loads. This is not quite enough to drive the MOC3011, nor can it be connected directly to an SCR or triac, because computer common is not normally referenced to one side of the ac supply. Standard 7400 series gates can provide an input compatible with the output of an MC6820, MC6821, MC6846 or similar peripheral interface adaptor and can directly drive the MOC3011. If the second input of a 2 input gate is tied to a simple timing circuit, it will also provide energization of the triac only at the zero crossing of the ac line voltage as shown in Figure 11. This technique extends the life of incandescent lamps, reduces the surge current strains on the triac, and reduces EMI generated by load switching. Of course, zero crossing can be generated within the microcomputer itself, but this requires considerable software overhead and usually just as much hardware to generate the zero-crossing timing signals.

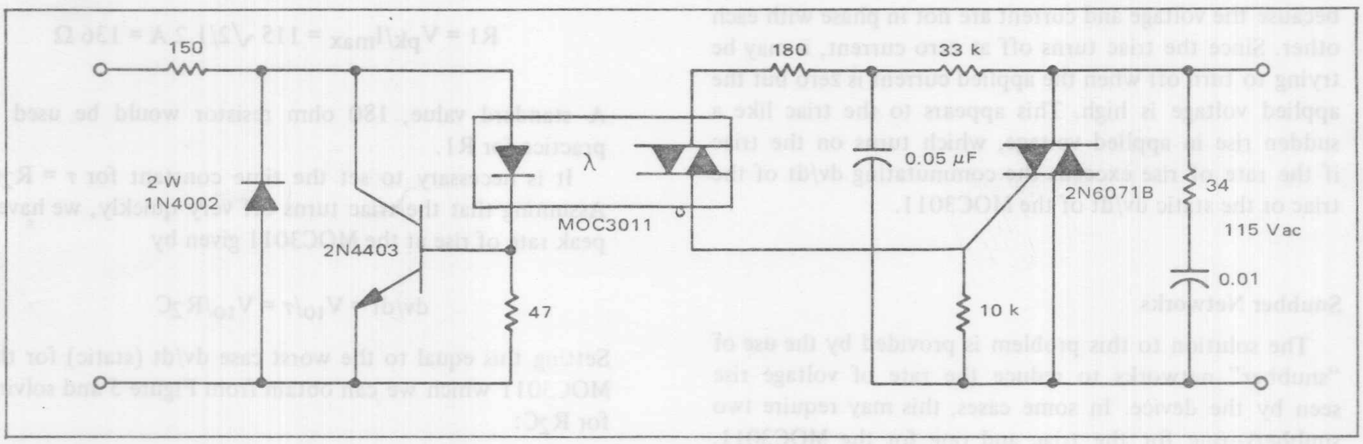


FIGURE 10 — Solid-State Relay

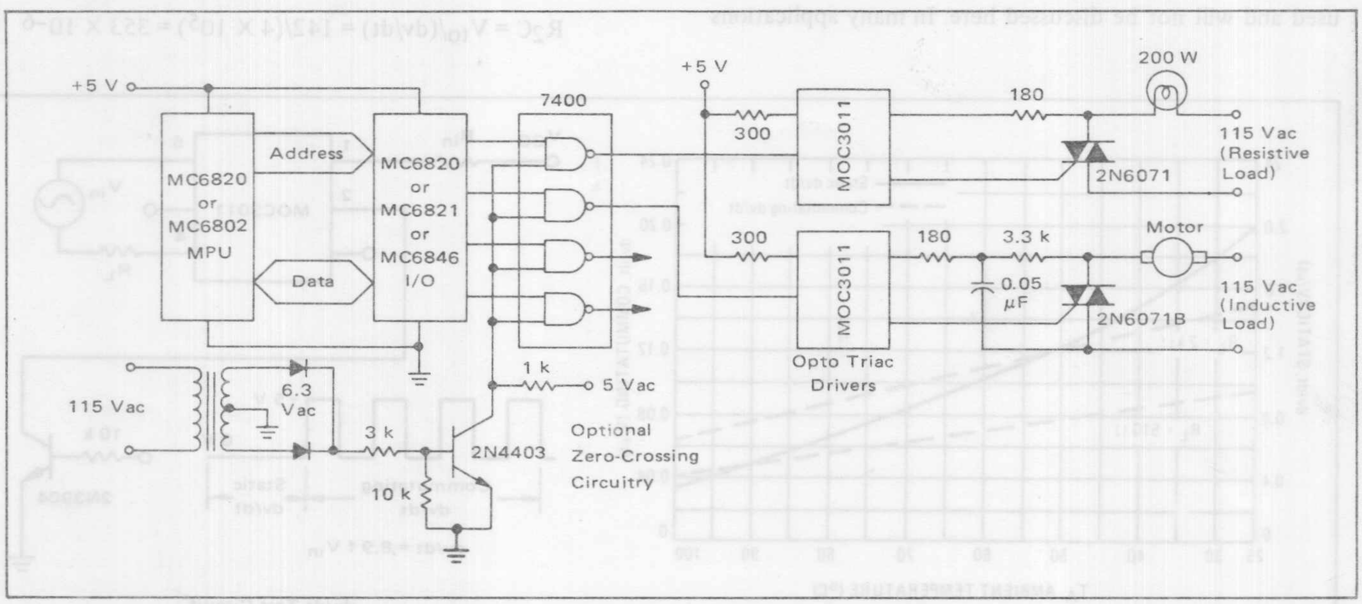


FIGURE 11 — Interfacing an M6800 Microcomputer System to 115 Vac Loads